DEPARTMENT OF COMMERCE
BUREAU OF FISHERIES
HENRY O'MALLEY, Commissioner

PROGRESS IN BIOLOGICAL INQUIRIES
1925

By WILLIS H. RICH
Assistant in Charge of Scientific Inquiry

APPENDIX I TO THE REPORT OF THE U. S. COMMISSIONER
OF FISHERIES FOR 1926

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INTRODUCTION

The work of the division of scientific inquiry during 1925 gave unusually encouraging and satisfactory results. Each major investigation distinctly contributed to our knowledge of fish and the fisheries, and both the volume and the quality of such contributions were unusual.

The policy of stressing the study of the immediate rather than the ultimate causes of fluctuations in the abundance of fish of each species was continued. The practical value of the information resulting from such studies is being recognized more and more, and solicitations for further investigations of this nature are increasing; but in spite of larger appropriations for such work, it has been impossible to respond to all of these requests. While appreciation and support of the work of the division is distinctly gratifying, it is realized that such interest entails increased responsibility in addition to the greater opportunity for public service. Every effort has been and will continue to be made to meet this responsibility as ably as possible.

There has been no change in the policies of the division, as outlined in the reports for the past few years. The division of the work into major investigations has been continued, emphasis having been placed on those giving the greatest promise of results of practical importance in the conservation and development of our fishery resources.

[1] Appendix I to the Report of the United States Commissioner of Fisheries for 1926. B. F. Doc. No. 1003.

True conservation of such resources as the fisheries means not only guarding them against depletion but making use of them to the greatest possible extent compatible with their perpetuation. Experience with domestic animals has taught us that the normal production of individuals is in excess of the number required to maintain the species, and that man may spend this excess without exhausting the capital stock. Our experience with domestic animals shows further, however, that the amount of this excess stock varies from year to year. In some years production is especially good, and then a greater number of animals may be utilized; but in other years the excess production is negligible or the stock may drop even below the level of maintenance, due entirely to causes outside the control of man. Although not so clearly apparent, the same thing is true of stocks of wild animals, including fish.

The difficulty is to determine from year to year what the excess production is and how much of the stock may be taken by man without endangering the future supply. This is especially difficult in the case of fish, which are, for most of their lives, out of reach of direct observation. In the case of stocks of domestic animals, or even of wild land animals and birds, it is possible to determine with considerable accuracy their population and the increases in their numbers from year to year, but in the case of fish this is practically impossible. Yet information of this kind is just as essential for the proper care of our fishery resources as it is for the care of land animals, whether domestic or wild. It will take more effort and more time to determine the yield of our aquatic resources from year to year and the causes of the fluctuations in the yield, but this expenditure will be amply justified by the more intelligent care we will be able to give them.

A new branch of applied science, aquiculture, is being developed and may be expected eventually to include the care of our aquatic resources in much the same way that agriculture takes care of our land resources. The problems of aquiculture are the more difficult ones, perhaps, but it is certain, nevertheless, that this science must be developed as agriculture has been—on a firm foundation of scientific facts. We must know the causes of fluctuations in the yield from year to year and how these fluctuation may be controlled, if that be possible, if we are to increase the productivity of our water areas and maintain it at the highest level.

Cooperation with the bureau by the States in conducting investigations was continued with very satisfactory results. During the past year work was conducted in cooperation with the States of North Carolina, South Carolina, Florida, Texas, Michigan, Wisconsin, Washington, Oregon, and California, and additional work is planned for the immediate future. The States provided men, laboratories, boats, and other equipment, and by this means the division was able to extend its activities far beyond the limits set by its own appropriations.

Perhaps the greatest difficulty in the way of the proper development of the work of the division lies in securing properly trained men interested in fishery investigations. More investigators are needed on our own staff, and frequently we have requests from State organizations for trained men, yet the greatest difficulty is experienced in finding really qualified investigators. It is hoped that some

of our universities will take notice of this demand and train men qualified to undertake work of this kind.

Two important general conferences dealing with the scientific investigation of fishery resources were held during the year. The first of these was called by the Commissioner of Fisheries on January 9, at the solicitation of State authorities and private persons interested in the welfare of the oyster industry, for the purpose of considering the various problems confronting that industry. Producers and distributers of oysters and the various State shellfish commissioners were represented, more than 50 persons being in attendance.

The second conference was called by the Secretary of Commerce on May 22 to consider plans for saving certain of the important Atlantic-coast fishery resources from further depletion and ultimate commercial destruction. It was attended by representatives of the various fish commissions of the Atlantic and Gulf States. Among the subjects discussed were the fisheries for shad, sturgeon, and lobsters, the control of fisheries in boundary waters, and the destruction of undersized or immature fish. The conference requested the Secretary of Commerce to appoint, with the approval of the governors of the interested States, a commission to work out the various problems pertaining to the rehabilitation of the lobster, shad, sturgeon, and other fisheries of our coastal waters, and agreed as to the necessity for concerted action to prevent their further depletion.

The following progress reports, covering the more important investigations conducted by the division during the calender year 1925, were prepared, in the main, by the investigators in charge.

INVESTIGATIONS OF FISH AND FISHERIES

ATLANTIC COAST

LIFE HISTORIES AND MIGRATIONS OF COD, POLLOCK, AND HADDOCK

This investigation, which was begun in April, 1923, was continued during 1925, when 15,260 cod, pollock, and haddock were tagged in localities ranging from Petit Manan, Me., to southern Massachusetts. Many of these fish, as well as fish tagged in 1923 and 1924, were recaptured during the year, and data relating to migrations, rate of growth, and age with respect to size were collected. A statistical summary of the results gained from the tagging experiments is given in the following tables:

TABLE 1.—*Number of cod, pollock, and haddock caught, and rate of capture per hour, during the years 1923–1925*

	1923	1924	1925
Number of cruises	7	9	16
Days of actual fishing	43	51	76
Hours of actual fishing	333	318.5	461
Number of cod tagged	7,618	6,209	10,420
Number of pollock tagged	2,215	916	949
Number of haddock tagged	411	3,223	3,891
Total number of fish tagged	10,244	10,348	15,260
Average number of fish tagged per hour	30.76	32.5	33.1

TABLE 2.—*Catch of fish according to localities*

	1923	1924	1925
Rhode Island			1
Massachusetts south of Cape Cod	10,231	4,384	6,142
Massachusetts north of Cape Cod	13	163	314
New Hampshire		8	5
Maine		5,793	8,798
Total	10,244	10,348	15,260

TABLE 3.—*Number of recaptured fish reported up to December 31, 1925*

	Recaptured				Total for each species
	1923	1924	1925	Total	
Cod tagged in 1923	156	91	32	279	
Cod tagged in 1924		206	245	451	
Cod tagged in 1925			578	578	1,308
Pollock tagged in 1923	11	25	5	41	
Pollock tagged in 1924		4	20	24	
Pollock tagged in 1925			7	7	72
Haddock tagged in 1923		5	1	6	
Haddock tagged in 1924		14	34	48	
Haddock tagged in 1925			33	33	87
Grand total of recaptures					1,467

In addition to these there are 38 records of cod recaptured a second time. No marked pollock or haddock were caught more than once, with the single exception of pollock No. 16,418, which was taken a second and a third time.

The regions of Mount Desert and Platts Bank, Me., have proved to be of unusual interest as experimental tagging grounds. Platts Bank, an isolated ledge in the Gulf of Maine, has an area of about 35 square miles, a depth 29 to 50 fathoms, and hard bottom such as cod prefer. Except for the north prong of Jeffreys Ledge, 11 miles west, it is surrounded for many miles by soft bottom, which cod usually avoid, and depths of 60 to 100 fathoms. During June and July, 1925, 604 cod were tagged on Platts Bank, and by the middle of November 13 per cent of these had been reported recaptured. This relatively high percentage is remarkable when it is considered that almost all recaptures were made by several Portland vessels fishing there in October and November and by the *Halcyon* during 7 days' tagging.

Scale samples were taken from all cod tagged in 1925 as well as from miscellaneous fishes. Over 10,000 scales, each from a different fish tagged in 1924, have now been mounted for study. It is believed that an analysis of these scales will give valuable data on the age, with respect to size and rate of growth, of various stocks of cod, pollock, and haddock along the New England coast.

A preliminary report on the Nantucket Shoals cod is now in course of preparation. This is practicable because it has been found that the stocks of cod inhabiting this region have carried out migrations of the same sort from year to year and that their lives differ in several important respects from the lives of those occurring north

and east of Cape Cod. Consequently the Nantucket Shoals fish can be treated as a separate unit.

The outstanding results of the fish tagging up to December, 1925, were as follows:

1. Nantucket Shoals: Cod tagged here in 1923, 1924, and 1925 have migrated each fall to the shore waters of Rhode Island, Long Island, and New Jersey. A few have been recaptured in South Channel, and only stragglers were taken north of Cape Cod or on Georges Bank. The majority were caught on Nantucket Shoals where they were tagged.

2. Stellwagen Bank, Massachusetts Bay: From a small number of cod tagged on this bank, two recaptures were made off Cape Ann and two off Rockaway, N. Y. There is therefore an indication of a migration both north and south of Stellwagen.

3. Portland to Boothbay Harbor, Me.: Most of the recaptures made of these fish have been extremely local, but a few tagged cod migrated offshore to Jeffreys Ledge and Platts Bank. The exceptional recaptures were made, one each, at Dennis (southern Massachusetts), Stellwagen Bank, and Grand Manan, New Brunswick.

4. Platts Bank: There were recaptured 18.3 per cent of the 218 cod tagged here in 1924, and 13.1 per cent of the 604 tagged in 1925. All recaptures were local except three, one at Harpswell, Me., and two near Chatham, Mass. Therefore, no migration from this bank was noted, but the local intensity of the fishing with respect to the stock of cod evidently was great.

5. Mount Desert: Thousands of cod were tagged here in 1924 and 1925. Nearly all recaptures were made locally, but enough records were received to show that a small migration to the Bay of Fundy occurred. A single cod tagged here was recaptured on Nantucket Shoals, but this is the only record from below Cape Elizabeth, Me. Local fishing evidently was very intensive, for up to the 1st of December 31.8 per cent of 308 cod tagged in April, 1925, and 17.7 per cent of 1,303 cod tagged in May had been recaptured.

Information concerning the migrations of pollock is not sufficient to permit of definite conclusions. The 72 returns of fish tagged from 1923 to 1925 show that 60 were recaptured locally, in many cases a year or more after tagging, and 12 made long migrations. From Nantucket Shoals 4 tagged pollock were recaptured in South Channel, 1 on Georges Bank off Massachusetts, 1 on Cashes Bank, and 1 off Petit Manan, Me., and 3 in the lower Bay of Fundy, Canada. One Platts Bank pollock was taken at Burnt Island, Me., and one Jeffreys ledge fish was recaptured off Sable Island, Canada.

Of 87 haddock records, several were incomplete, 20 fish made long migrations, and the remainder were taken locally. From Nantucket Shoals 8 were recaptured in South Channel, 1 on Georges, 3 on Stellwagen Bank, and 1 on Platts. From Boothbay Harbor, Me., 1 haddock migrated to Platts, and from Mount Desert 2 were taken in New Brunswick, 3 on Platts Bank, and 1 in South Channel adjacent to Nantucket Shoals.

This work was efficiently conducted by W. C. Schroeder under the general direction of Dr. H. B. Bigelow of the Museum of Comparative Zoology, Harvard University. It is planned to continue the investigation during 1926, when offshore fishing banks, as well as the usual shore grounds, will be fished.

Throughout the past year the investigations of the spawning grounds and early development and distribution of young cod, pollock, and haddock in New England waters were continued by Dr. Charles J. Fish and Marie P. Fish assisted by Robert A. Goffin. Particular attention was given to Massachusetts Bay in order to determine its value as a production area for cod. Fourteen cruises were made on the *Fish Hawk*, covering the area between Ipswich Bay and Provincetown. At 41 stations, physical observations were made and fish eggs, young fish, and plankton were collected, counted, and identified. Drift bottles were used to determine current movements. The results so far indicate that a very definite and constant counterclockwise drift carries out all cod eggs spawned in Massachusetts Bay before they hatch. Throughout the breeding season eggs were found in abundance, particularly about the Plymouth grounds, but the collections of 14 cruises failed to yield a single young cod. Charts based on the distribution of eggs in various stages of development show clearly the spawning centers and the drift of the eggs, the greater proportion of late stages having been taken about the Provincetown region as they were leaving the bay.

The records of drift-bottle discoveries also substantiate the above conclusions. Of 141 set out during the year, 43, or 30.5 per cent, were returned. On February 6 and 7, 90 were set out and 19, or 27.7 per cent, were recovered within a few days along the inner arm of the cape, having followed the circulatory drift until they grounded. Most of them entered Provincetown Harbor. Three escaped the cape and appeared on the Nova Scotian coast between July 2 and August 27. Two circled the cape and were found on the south shore of Nantucket. No record has been received of 11 placed north of Massachusetts Bay between Cape Ann and the Isles of Shoals on April 7. On May 20 to 22, 40 were again set out in the area covered in February. A line also was added along the north shore from Cape Ann to Boston and one from Cape Ann to a point off Provincetown. Of the 10 placed along the northern shore, 5 were recovered, all having soon reached the beach after drifting in a southerly direction. Of the 10 placed along the outer entrance to the bay, 2 were recovered. Apparently they had circled into the bay and grounded on their way out. One reached shore near Race Point on the outer tip of Cape Cod, and the other was taken drifting 2 miles from land, having successfully passed the cape.

Of the 20 placed in the bay, 11 were recovered. One had traveled from the inner edge of Stellwagen Bank to a point 75 miles S.E. by S. of Highland Light, Provincetown; while another, starting far within the bay, reached Edgartown on Marthas Vineyard. All of the bottles clearly indicated the circular drift into the bay from the north and out to the east. There, apparently, a division takes place, part moving north toward Nova Scotia and part south around Cape Cod.

As the lack of a suitable ship prevented an extension of the survey to the outer waters to determine the fate of the cod eggs after leaving the bay (the next logical step in the program), a continuation of the work of the past year was decided upon to serve as a check on the previous observations. Monthly cruises are being made, covering much the same area as last year, except that stations

have been added as far offshore as possible and a line extended from Cape Ann to Boston to determine, if possible, the quantity of eggs that enter the bay from the north.

An important point in the present investigation is to determine whether the past year was a normal one or whether unusual physical conditions were responsible for the total absence of young cod throughout the breeding season. It was interesting, therefore, to find that the water temperatures during the first cruise (December 15 to 19, 1925) were almost identical with those taken over the same period last year. The cooling apparently took place at the same rate in each year.

TABLE 4

Massachusetts Bay	Dec. 16 and 17, 1924	Dec. 15 to 19 1925
	°C.	°C.
Average surface temperature	5.02	4.83
Average bottom temperature	5.46	4.88
Warmest station (surface)	5.93	5.60
Warmest station (bottom)	6.10	5.80
Coldest station (surface)	3.80	2.80
Coldest station (bottom)	4.20	2.80

Due to the absence of young cod in the collections, no information was obtained as to their food and enemies. The physical conditions necessary for the successful hatching of cod are fairly well understood, but almost nothing is known about the biological environment of the cod and its relative importance in determining success or failure in any particular season or locality. Experiments along these lines are being conducted with larval fish obtained from the hatchery at Gloucester.

In addition to data concerning the cod, pollock, and haddock, the present investigation has increased our knowledge of the distribution, life histories, and occurrence, in the area covered, of 23 other species of young fish that have been identified from the collections.

MACKEREL INVESTIGATIONS

During the 1925 mackerel fishing season, investigations on this important fishery were begun. These consisted principally of tagging experiments and the collection of biological data and material such as scales and records of size and maturity for future analyses. Much of this work was carried on in cooperation with the division of fishery industries, which has begun a program intended to accumulate special statistics on fluctuations of the mackerel fishery.

The tagging experiments were carried on at Provincetown, Woods Hole, and Casco Bay, approximately 5,600 mackerel being tagged during the season. Of these, 286 have been reported as recaptured, some of them having been taken as far east as Fire Island, N. Y., and as far north as Casco Bay. Any general conclusions as to the migrations of mackerel, however, must await the extension of these operations in future years.

Mullet investigations.—The investigations of the mullet in the South Atlantic States was continued during 1925 by Elmer Higgins, director of the Key West biological station, and several assistants. John C. Pearson, Russell F. Lord, and Robert O. Smith were employed in this work at various times during the year and later were assigned to other problems.

The mullet fishery, yielding approximately 40,000,000 pounds of products annually, is widely scattered, being prosecuted with varying intensity from North Carolina to Texas. The fishery has seriously declined in several areas, notably North Carolina, and is in need of conservation. Because of the nature of the fish, local conditions are of unusual importance, but on account of the lack of sufficient funds to properly conduct so extended an investigation, it was necessary to center activities at one shore station only and to conduct studies of a fundamental nature having bearing upon the whole fishery. These studies included racial localization, migrations, growth, age, and racial analysis of the local stock of fish.

The question of racial localization is of practical importance to the regulation of the fishery. Previous work has shown that mullet from North Carolina and Florida differed to a significant extent in measurements of the heads, indicating the existence of distinct races and an absence of the extensive migrations commonly attributed to these fish. Over 7,000 additional measurements made in 1925 on the North Carolina stock agreed completely with previous observations and added to the evidence already collected.

Additional data on the so-called Cape mullet strengthen the assumption that these fish are a distinct division of the local stock because of a different variation in the measurements of the head and higher rate of growth. This question is complicated by migrations and other factors, however, and must be investigated further during the coming spring and summer before definite conclusions can be reached.

Migrations of the mullet have been studied by observing the composition of the local population during each month of the year, by collecting records of the commercial runs, and by the liberation of tagged fish. Commercial catches and special hauls were sampled throughout the year, the catch was analyzed for age and size composition, and physical measurements were taken. In all, approximately 4,800 mullet were measured during 1925.

The records of the commercial runs of fish were collected for 1924 by personal canvass of the principal dealers of North Carolina, but as this method of obtaining records was unsatisfactory, those for 1925 were collected by weekly questionnaires. It was considered desirable to test the popular belief that the runs of mullet depend upon weather conditions. The imperfect catch records of 1924, when compared with temperature records, showed a high degree of negative correlation, and it is expected that details of the effect of temperature and other weather conditions upon the movements of the fish can be worked out from the more accurate records of 1925.

Although the analyses of the racial stocks of Florida and North Carolina have progressed far enough to convince the investigators of the falsity of the popular views on the extent of migrations, it was

thought best to test these preliminary findings and provide an objective proof of the wanderings of the mullet. Accordingly, a tagging experiment was undertaken, and 3,000 mullet were tagged and liberated near Beaufort, N. C. About one-third of the fish tagged were in their first year and the rest were in their second. By the end of December, 34 tags had been returned by fishermen.

TABLE 5.—*Summary of mullet-tagging experiments*

Month	Number tagged	Number returned	Locality of recapture		
			North of Beaufort	At Beaufort	South of Beaufort
June	994				
July	702	11	3	8	
August	231	7	3	3	1
September	584	10	3	2	5
October	516	5			5
November					
December		1	1		
Total	3,027	34	10	13	11

All tagged fish were recaptured within the boundaries of North Carolina except one near Georgetown, S. C., 170 miles from Beaufort. This fish traveled the maximum distance from the place of liberation and did so in 52 days. The longest time that elapsed between liberation and recapture was 119 days. While these returns are insufficient to outline fully the migrations of the mullet, the indications are that the southward migration along the coast begins, at Beaufort, in August, continues during September, and is completed in October. Some fish, however, remain in fresh or brackish waters of the rivers during the winter, apparently not taking part in the annual migration. These observations are in accord with popular opinion in this district. The experiment further indicated that North Carolina mullet do not continue the journey to Florida, as is generally supposed, but definite conclusions as to the extent of the migrations must be withheld until further data are available. It is planned to extend the tagging experiment another year to Florida waters.

Material progress has been made in the study of the growth of the mullet. Evidence has been gathered from a study of monthly curves of length frequency, from the study of scales, and from the tagging experiment. It has been found that the supposed typical North Carolina stock reaches a body length of approximately 150 millimeters in the first year and nearly 300 millimeters in the second. The maximum age is probably 5 or 6 years. Growth begins in May and extends into October. Certain discrepancies in the various data are probably due to the mixing of distinct racial stocks, and it is hoped that these and other details may be worked out from scale studies that are now under way.

Analyses of the commercial catch at Beaufort show that the July, August, and September catches consist of second-year fish (the I group) and that October runs are mainly composed of either older fish of the third or fourth year, which are approaching the spawning condition, or else of fish less than one year old (the O group). In 1924 the older fish (II and III groups) predominated, but in 1925 the

cape mullet, all of the O group, were exceedingly abundant, and an unusually large catch was made during the season. This seems to indicate that great fluctuations in yield may result from natural causes, and that the phenomenon of dominance of year classes, so clearly recognized in other fisheries, may be of equal significance and practical importance in the case of the mullet.

While there are many indications that the mullet fishery of North Carolina has reached an advanced stage of depletion, the problem of adequate protection is extremely complicated. Because of the uncertainty as to the origin and identity of the individual stocks in these waters and their relative need of protection, no definite recommendations for regulation of the fishery have been offered. It is hoped, however, that a practical plan can be devised during the coming year.

Investigation of the summer fisheries of Pamlico and Core Sounds, N. C.—At the request of the State fisheries commisssioner, an investigation of the summer fisheries of Pamlico and Core Sounds, N. C., was undertaken to determine the action upon the fish stock of the two chief types of gear in use in these fisheries—namely, pound nets and long-haul seines. Five fishing stations were chosen at which to conduct the investigation, where unsorted samples of the catches made were analyzed once each week from June 8 to November 3, 1925. John C. Pearson, temporary assistant, performed all of the field work and studied many of the data under the supervision of Elmer Higgins.

It was discovered that of the two species that formed the greater part of the catch in pound nets (gray trout and harvest fish), about half were below the legal or marketable size limit. The greatest waste of gray trout occurred during June and July, when 54 and 30 per cent, respectively, were below the legal limit of 9 inches. The greatest waste of harvest fish, however, took place in August, September, and October, 65, 95, and 97 per cent, respectively, being below market size then. Of the two chief species caught by long-haul seines (spotted trout and croakers), practically no destruction of unmarketable fish occurred until October, when 14 and 13 per cent, respectively, were destroyed.

The total yield of the sea trouts in 1923 amounted to 28.3 per cent of all marine food fish in North Carolina, perhaps 90 per cent of these being gray trout caught by pound nets, The catch of harvest fish, however, amounted to only 3.7 per cent. No single system of protection for both of these species has been discovered so far, hence it was decided to recommend the establishment of a closed season until August 1 on all pound nets fished in the sounds, for the protection of the more important species. As the gray trout has practically completed its spawning by this time, the closed season prohibiting the destruction of unmarketable fish would afford almost complete protection.

A preliminary report dealing with these data was prepared and presented at the meeting of the State Fisheries Commission on December 8. Acting on the information contained therein, the commission passed a rule establishing the closed season as recommended. The promptness of this action on the part of the State is most encouraging, and it is believed that much good will result.

Investigation of the marine fisheries of Texas.—A growing belief that complete depletion of the Texas marine fisheries is imminent has resulted in demands for an investigation to determine the causes of the present shortage of the fish supply. Accordingly, the work was undertaken, and Elmer Higgins and Russell F. Lord, junior aquatic biologist, visited the Texas coast during July and August for the purpose of conducting a preliminary survey of the fisheries as the basis for further plans. A report was prepared and submitted, describing the fisheries, discussing past and present conditions as discovered by a study of all available records, summarizing the present knowledge of the habits of commercial species, outlining the need for biological research, and recommending changes in the method of fishery administration.

The report especially emphasizes the lack of records competent to show the real state of the fishery, and recommends the adoption of a system of statistics that will be of economic value and also provide the basis for a biological examination of the abundance of fish. Necessary changes in the administrative machinery to permit the development of a rational program of conservation also are outlined.

Robert O. Smith, temporary assistant, was detailed to the field work on November 18, and headquarters were established at Corpus Christi, Tex., where a biological examination of the commercial fishery was begun with special reference to the question of depletion. In addition, the life histories of the chief commercial species—redfish, spotted sea trout, and black drum—will be studied with the view of discovering adequate and equable methods of protection.

The cooperation of various States in the investigations of fisheries of the South Atlantic and Gulf States has been most gratifying. North Carolina has contributed to the mullet investigation by supplying a 26-foot open launch for the the exclusive use of the investigators from May to November. The investigation of the Pamlico Sound region was made possible by the furnishing of a comfortable and seaworthly 40-foot cabin cruiser and crew with all expenses paid for its operation from June to November. Half of the expense of purchasing samples of fish also was borne by the State.

SMELTS AND SALMONIDÆ

Early in the year, Dr. William C. Kendall completed and submitted for publication a report upon the natural history of the smelt (Osmerus) and a synopsis of both salt-water and fresh-water smelt fisheries of Atlantic waters, particularly those of North America and more especially of the United States, to which are added discussions of smelt culture and conservation. The section of the report concerning the natural history of the smelt comprises both a compilation of data scattered through many publications and records from the author's personal observations during more than 30 years. In making the compilation it was somewhat surprising to find that there was so little published information concerning the habits and life history of the smelt. The natural history account pertains to both salt and fresh-water smelts and comprises discussions of geographical distribution or "range," habitat, size, food, breeding habits, enemies, etc.

Concerning the smelt fisheries of the eastern United States and Canada, it is shown that the fishery of the United States has progressively declined in quantitative importance from the southern limits

northward, so that at the present time Maine has virtually the only commercial smelt fishery of the Atlantic States, and even that has greatly fallen off in recent years. It is also shown that most of the smelts consumed in this country come from the Canadian Provinces, principally from New Brunswick. In this connection the smelt fisheries of Massachusetts, Maine, and Canada are historically discussed and compared, and from the comparison it appears that while the smelt fishery of the United States shows a marked decline, that of Canada has greatly increased in economic importance. Some of the causes to which the decline in the United States is attributed are as follows:

1. Lack of effective regulation of methods, time, and places of fishing.
2. Lack of protection of the fish during the breeding season and failure to protect immature smelts.
3. Physical and chemical obstructions to the ascent of streams for spawning.

Doctor Kendall has also been occupied with the preparation of a paper pretaining to the life history of the smelt as revealed by scale studies and measurements of specimens and has studied hundreds of scales and specimens. The question of species and races of smelts is also being considered.

Scale readings of marine smelts indicate that such fish first spawn at the age of 2 years and that the great majority of smelts that ascend the streams to spawn are of that age. Three-year fish are less common, those four years old still fewer in number, and five-year fish are comparatively rare. For example, of 1,000 smelts taken in the same brook in two successive years (1924 and 1925), 896, or nearly 90 per cent, were 2 years old; 75 individuals were 3 years, 25 were 4 years, and 4 specimens appeared to be 5 years of age. In October and November, 1925, 70 out of 132 smelts taken at random from a dealer in 1 and 2 pound lots, or something over 50 per cent, were in their second year; 59 individuals were in the third, 2 in the fourth, and 1 in the fifth year. Had these fish lived until the next spring they would have reached exactly the ages of 2, 3, 4, and 5 years.

In the report concerning the conservation of the smelt fishery, Doctor Kendall expresses the belief that if the fish were to be adequately protected and the fisheries properly regulated, the fishery in Maine might be rehabilitated to a great extent.

Analysis of various data, of which the foregoing figures are an example, leads to the conclusion that the maximum productivity to which the smelt fishery can be brought depends largely upon the undisturbed breeding of 2-year-old smelts, and this depends upon the attainment of that age by the immature smelts. In the smelt fishery great quantities of immature smelts are destroyed, and it is impossible to prevent this destruction as long as certain prevailing methods of fishing are employed; but the destruction may be reduced to a minimum by establishing refuges where no smelt fishing except by hook and line will be permitted. Accordingly, Doctor Kendall recommends that all smelt fishing, except by hook and line, be prohibited in tidal waters such as arms, coves, creeks, etc., one-half mile or less in width. It is furthermore advised that the closed season for breeding smelts begin March 1.

In Maine, fresh-water streams flowing directly into tidal water come under the jurisdiction of the Inland Fish and Game Commission instead of the Sea and Shore Fishery Commission, and the law permitting fishing for fresh-water or lake smelts during their breeding season applies on these streams. As smelts can breed only in fresh-water streams, the marine smelt is afforded no protection during the spawning runs. A law should be made distinguishing between tide water and lake tributaries, and the protective law of the Sea and Shore Fishery Commission should be extended to cover the former.

The analysis of the data pertaining to the fresh-water smelts is still in progress. The smelts of the lakes afford entirely different problems from those of the salt-water fish, and it is anticipated that these will be worked out, as far as the data will permit, in the near future.

LARVAL FISHES

An unusual opportunity was afforded by the *Arcturus* expedition (see account under heading "Oceanography") for the study of larval fishes, their distribution over large areas in the Atlantic and Pacific Oceans, their embryology, food, and enemies, the description of unknown forms as well as of new stages of known species, and a study of the conditions of life under which they exist in the open sea. The examination of the young fishes collected by the expedition is being carried on by Marie Poland Fish.

Throughout the cruise, larval and postlarval fishes were found distributed everywhere over the ocean, but the number of species and the actual abundance of specimens were strikingly different in the various regions investigated. From Bermuda southward, in the Sargasso Sea area, every haul of the plankton nets and Petersen trawls yielded quantities of young fishes, often 10 to 20 species at a time. Although this part of the Atlantic had been visited by heavy storms for some weeks, the larval fishes seemed to thrive well, if one can judge from the immense number of uninjured specimens taken. It would appear, also, from the collections made here, in a region where conditions typical of the open sea exist, that by far the greatest proportion of ocean fishes spend the early part of their lives at the surface. Of 40 species recorded and described by Mrs. Fish in late February and early March, approximately 80 per cent were found always at the surface, 10 per cent at depths of 100 to 200 meters, and 10 per cent below these depths.

The Pacific Ocean, in contrast to the Atlantic, although swarming with animal life, yielded relatively few larval and postlarval fishes from March until the middle of June. Although nearly every haul brought in a few larvæ, and the number of species represented over the whole period was no less, the total number of specimens was much smaller than in the Atlantic during late February, March, and July.

The embryology and early development has been worked out for five species of flying fish obtained during the cruise, some of them from nests of Sargassum weed bound together by tough threads of secreted material. The unusual modification of the fins was found to be evident even in the egg. The eggs of 15 different fishes, the development of which was previously unknown, were hatched in the laboratory. At the completion of the expedition, 161 species

of larval and postlarval fishes had been figured and described by Mrs. Fish, and further study of the collections undoubtedly will reveal many more.

In connection with the work on tropical larval fishes, it has been possible to identify many of the extensive collection of larval fish slides made for the bureau by the late W. W. Welsh.

CHESAPEAKE BAY

The report bearing on the fish and fisheries of Chesapeake Bay, which is being prepared under the direction of Dr. Samuel F. Hildebrand, assisted by William C. Schroeder, Isaac Ginsburg, and Irving L. Towers, has been virtually completed and will be submitted shortly for publication. A total of 107 salt and brackish water fishes, of which 3 appear to be new, are described and discussed therein. The descriptions in the report, with comparatively few exceptions, were drawn up directly from specimens. Whenever specimens were not available and descriptions were compiled or copied from published accounts, it was so stated. Keys for families, genera, and species are included. A special effort was made in the discussion to point out the most evident field marks distinguishing the various species. Brief accounts of the food and feeding, spawning and life history, size attained, relative abundance, and commercial importance of each species are included. A considerable number of graphs showing the fluctuations and relative abundance over a period of years for several important commercial species also have been prepared.

NORTH AMERICAN COMMITTEE ON FISHERY INVESTIGATIONS

Two meetings of the committee were held during the calendar year 1925, one in May and the other in November. The first one was held at New York on May 8, and W. A. Found, A. G. Huntsman, and J. P. McMurrich, representatives of Canada, and H. B. Bigelow, Henry O'Malley, and Willis H. Rich, representatives of the United States, were present. In addition to these, J. P. Babcock, of British Columbia, N. B. Scofield, of the California Fish and Game Commission, F. W. Wallace, of the Fishing Gazette, New York City, and O. E. Sette, of the Bureau of Fisheries, were in attendance.

The principal matter under consideration was the planning of proper methods for the collection of statistics of the fisheries on the banks of the western North Atlantic, with particular reference to the mackerel, cod, and haddock. Suggestions were made for improving the present collection of statistics, and a special committee was appointed to consider the details more fully. The program of the United States Bureau of Fisheries in studying problems of the cod fishery, with particular reference to the spawning of the cod in Massachusetts Bay, and the movements of the adults by means of tagging experiments was outlined. The project of tagging mackerel also was discussed, and it was urged that further steps be taken to investigate the Atlantic halibut.

The second meeting was held at Montreal on November 6, W. A. Found, A. G. Huntsman, and J. P. McMurrich, of Canada, and H. B. Bigelow and O. E. Sette, of the United States being present.

The importance of securing the interest and cooperation of all nations participating in the fisheries on the American side of the North Atlantic was discussed. The committee decided to extend an invitation to membership and representation on the committee to Portugal, and the Canadian Government was asked to communicate with Portugal that effect. Participation by Portugal would round out the representation on this committee, which already includes Newfoundland, France, Canada, and the United States. All of these countries participate in the fisheries of the American North Atlantic, which yield in excess of 1,000,000,000 pounds annually.

The special committee appointed at the previous meeting to consider recommendations for the improvement of statistics of the fisheries reported its recommendation that statistics be collected so as to make available information on the fishing effort, as shown by the number of men and the number of fishing days involved in the production of the total catch. These recommendations were approved by the committee.

Action was also taken to secure the cooperation of each country in transmitting annual reports of its statistics to the other members of the committee.

It was also recommended by the committee that there should be regular collection of data and material of the commercial fisheries in the form of measurements and scale collections from sample catches.

The progress during the past season in cod, haddock, and mackerel investigations and the drift-bottle experiments were reported to the committee.[2]

INTERIOR WATERS

COREGONINÆ OF THE GREAT LAKES

Dr. Walter Koelz has completed the first draft of a report on the systematic relationships and natural history of the coregonines of the Great Lakes and Lake Nipigon, and it is hoped that the manuscript will be ready for publication soon. Experiments also have been begun to test the constancy of racial characteristics in the lake herring. The superior quality of the Lake Erie herring has long been recognized by the trade, and a great deal of interest has been manifested in its introduction into other lakes. Fry have been liberated in Saginaw Bay in Lake Huron, and at Port Washington, Wis., in Lake Michigan. If the fish retain the characteristics they exhibit in Lake Erie, the experiment will have important consequences. Additions have been made to the collections of coregonines from the inland waters of eastern North America, principally through the courtesy of the Department of Biology of the University of Toronto, the museum of the University of Michigan, and the State museum of New York.

During the past year John Van Oosten spent much time in revising and greatly elaborating a paper on the life history of the lake herring (*Leucichthys artedi*) of Lake Huron. The new data were derived from a study of some 2,000 additional specimens and scales collected in 1924 and referred to in the last annual report. Altogether, some 4,000 herring and their scales, representing samples taken

[2] The details of the work of the United States Bureau of Fisheries on these subjects may be found on pages 3 to 7 of this report.

each year since 1921, have been measured and studied. From this series of samples it has been possible to follow the history of the commercial schools and year classes of herring through several successive years and to obtain a rather detailed life history of the species, and questions of importance were definitely settled. The data furnish information on a number of problems, such as the age composition of various commercial schools, the average lengths and weights of males and females at various ages, the variations in rates of growth, the norms for growth, the abundance of males and females, the age at sexual maturity, the races of herring, the effects of commercial fishing upon the fish stock, etc. The report will be submitted soon for publication.

Some progress has also been made during the past year in the study of the life history of the Lake Huron whitefish (*Coregonus clupeaformis*), but it is thought best to withhold a report until all the available material has been studied.

As in previous years, several weeks were devoted to the collection of additional herring and whitefish material.

PACIFIC COAST AND ALASKA

An outstanding feature of the work on the Pacific coast in 1925 was the establishment of the International Pacific Salmon Investigation Federation, organized at a meeting held in Seattle, Wash., on March 16 and 17 and attended by Federal and State fishery officials representing the United States, Canada, British Columbia, Alaska, California, Oregon, and Washington. A permanent organization was effected, pledged to the development of a cooperative plan for the study of the problems of production and building up the salmon runs. The following statement is quoted from the account of this meeting given in the Pacific Fisherman for April, 1925.

> The most important subject taken up was that of biological investigation. It was admitted that the existing knowledge of the salmon is far less than it should be; and a review of a few of the vital points on which there is no accurate knowledge whatever indicated the vast extent of ignorance on the subject that still exists * * *. The ground to be covered would include fish-cultural problems and other possible means of increasing the production of salmon as well as other questions concerning the life and habits of young and mature fish. It was decided that a definite plan should be developed for organized work along this line, details of which were delegated to a committee.

In carrying out its part of the program, the bureau has established a laboratory in Seattle in quarters kindly provided by the University of Washington, and Dr. W. H. Rich has been placed in direct charge of the salmon investigations. Another meeting of the executive committee of the federation, of which Commissioner Henry O'Malley is chairman, was held in Seattle on November 24. At this time Dr. C. H. Gilbert, Dr. W. A. Clemens of the Biological Board of Canada, Doctor Rich, and others presented their views relative to the proposed program of salmon investigations. Definite plans were presented for research work to be carried on during 1926.

The organization of this federation marks a distinct step forward in salmon investigations and will bring about a coordination of activities, which would do much to make our research program more complete and to hasten the collection of data of vital importance.

ALASKA SALMON

The investigations of the Alaska salmon conducted by Dr. C. H. Gilbert and Dr. W. H. Rich have yielded important information during the past year. The study of migrations by means of tagging experiments was continued, nearly 16,000 tags having been attached. Two thousand of these were put on in the Port Moller region of the Bering Sea, the remainder being used in southeastern Alaska. The results of the experiments conducted at Port Moller corroborated the findings of 1922 to the effect that the majority of the fish taken at that place are of local origin, spawning mainly in the Bear and Sandy Rivers. The experiments in southeastern Alaska furnished much information regarding the migrations of the various species of salmon among the complicated channels of this region, but the situation here is so complex that it is not possible to summarize the results briefly. During the year a report was published covering the results of tagging experiments in 1923, and a report on the tagging experiments of 1924 and 1925 is in course of preparation.

The intensive study of the important salmon runs at Karluk, Chignik, and the red-salmon streams of Bristol Bay has been continued by Doctor Gilbert. Weirs have been operated continuously since 1921 at Karluk and since 1922 at Chignik, and during each of these years the escapement of salmon to these streams has been determined by actual count of the fish passing through the openings in the weirs. Weirs have been maintained at Alitak and in Anan Creek also. The first returns from escapements of known size will occur on the Karluk River in 1926 and at Chignik in 1927. The results are awaited with much interest, and we can look forward to a series of determinations in successive years that should present evidence of the highest value. Through these investigations an attempt is being made to determine such correlations as exist between the number of spawning fish and the number of their progeny that return at maturity. This will give a measure of the total losses that occur from the egg to the adult from all causes combined, and will answer the all-important question as to the size of the spawning reserve needed to produce a run of the desired size.

Rapid progress has been made by Doctor Gilbert in the survey of the cycles and the annual composition of the red-salmon runs to the various streams of Bristol Bay. Extensive collections of scales from this region have accumulated and represent the runs of several years. The scales of some 15,000 red salmon included in these collections were read during the past year and the results tabulated.

SALMON OF THE PACIFIC COAST STATES

A series of salmon-marking experiments, which have been conducted for a number of years on the Columbia River by the bureau in cooperation with the Oregon Fish Commission, yielded valuable information during the 1925 season. Approximately 100 adult chinook and 50 sockeye salmon, which had been marked by removing certain of their fins when they were liberated from the hatcheries, were recovered as they returned to the Columbia River to spawn. The sockeyes represent the first returns from 100,000 yearlings that were marked and liberated during February, 1924. The recovery

of so large a number of 3-year-olds gives promise of exceptionally good returns from the experiment. The fish in another sockeye experiment, in which the young fish were liberated during the fall of their first year, should have been 5 years old in 1925, but no returns were received. This experiment seems to have been a total failure, as no 3 or 4 year olds were recovered. These results agree with those from former experiments in showing that when it is not possible to liberate sockeyes in a lake in which they can remain until the spring of their second year (which is their natural time of migration), they should be held in rearing ponds until that time.

About 50 of the marked chinooks recovered were 3-year-olds that had been marked at the Big White Salmon River hatchery during May and June, 1923, when they were about 5 months old. Here, also, the recovery of a large number of 3-year-olds gave promise of good returns as 4 and 5 year olds. This one year's returns from this experiment nearly equal the total returns from two former experiments, which differed from this one mainly in that the fingerlings were retained for about three months longer before being liberated. The greater returns from this experiment would indicate that the best time to liberate the chinooks that spawn in the Little White Salmon and Big White Salmon Rivers is during the spring of their first year. This is to be expected, for a study of the scales of the fish that spawn in those tributaries has shown that normally they migrate to the ocean within a short time after hatching.

In order to determine the best time to liberate fingerlings of the spring run of chinook salmon, a series of marking experiments was undertaken in 1925 at the McKenzie River hatchery. This series consisted of five markings with liberations ranging from May of the first year to March of the second.

In addition to conducting the marking experiments on the Columbia River, H. B. Holmes has been making a study of the blueback salmon of the Columbia. Representative samples of scales and measurements were collected from the commercial catch at intervals throughout the season, and observations were made of the seaward migrants and the spawning adults in the Okanogan River spawning district.

HERRING OF ALASKA

In the spring of 1925 a biological investigation of the herring of Alaska was begun by George A. Rounsefell, scientific assistant. During the summer a preliminary survey was made, and as many herring establishments as was possible were visited in the season, touching at Ketchikan, Craig, Killisnoo, and Port Walter in southeastern Alaska; Sawmill Bay, Prince William Sound, Seldovia, Cook Inlet, and Red Fox Bay; and Kodiak and Three Saints Bay in the Kodiak district. As a necessary preliminary to other work, a study was begun to determine what local races exist and the degree of variation between them. Racial samples were collected at many of the points visited, and various structural characters were studied. These data show clearly that the Pacific herring is not a homogeneous population.

The average vertebral count falls from 52.78 in Prince William Sound and 52.72 in Shuyak Strait to 52.50 in Cook Inlet, 52.45 in

southeastern Alaska, 51.78 in British Columbia, and 50.81 in California. This is an average difference of two vertebræ between 60° and 37° of latitude.

The proportion between the head length and the body length (without caudal) decreases as the body length increases. Conversely, the proportion between the anal fin insertion and the body length increases, demonstrating that the head and tail do not keep pace with the rest of the body in growth. On plotting the head length the curves show great differences, the percentage of head to body length curve for Russian Harbor falling 2½ per cent below the curve for southeastern Alaska, at 255 millimeters body length. Other characters used are the dorsal and anal fin ray counts and the distance parallel to the body from the tip of the snout to the end of the occipital bone on the back of the head, and to the dorsal, ventral, and anal fin insertions. These characters also show differences of undoubted statistical significance.

It may be stated, from what few data have been collected, that the herring of southeastern Alaska are quite distinct from those to the westward. There are decided differences between localities in southeastern Alaska although in general these are less than the differerences between southeastern Alaska and the districts to the west. The same is true of localities to the west. There are slight indications, from rough measurements, that the phenomenon of the dominant year class may be present, as in the Atlantic herring and the California sardine, but this requires corroboration.

Scales were collected from all of the samples measured and are now being examined to determine the age and rate of growth in each region. This may also shed more light on local races.

MARINE FISHES OF THE GULF OF VENEZUELA

A fairly representative collection of fishes of the Gulf of Venezuela was received during the year from Commander Paul P. Blackburn of the U. S. S. *Niagara*. This collection was turned over to Dr. Samuel F. Hildebrand for study. Doctor Hildebrand, assisted by Irving L. Towers, has made some headway in the classification of the species.

It is of interest to note that several species ranging both north and south of the Isthmus of Panama, as for example the bluefish, are well represented in the Venezuelan collection but were not present in the extensive collections made on the coast of Panama by Meek and Hildebrand.

INVESTIGATIONS OF SHELLFISH AND TERRAPIN

OYSTERS

Investigations relating to oyster culture were conducted by Dr. Paul S. Galtsoff in Georgia and at Woods Hole, Mass., and by H. F. Prytherch at Milford, Conn.

A survey of the oyster resources of Georgia, made in January, February, and March, covered 351 miles of the Atlantic coast between Savannah and St. Marys, and was made for the purpose of determining the degree of depletion of the natural oyster beds and what practical measures are necessary in order to increase the production of oysters in the State.

The natural oyster beds in Georgia are situated either along the shores of the rivers above low-water mark or in the open sounds. These beds are in the form of large reefs, composed chiefly of long, narrow oysters (the so-called "coon" oysters) of inferior quality. The bottoms of rivers in the tidewater region present a great variety of conditions from very soft mud, unsuitable for planting, to hard, sticky, blue mud suitable for oyster culture. Many of the natural oyster beds that are easily accessible and are situated in shallow water have become depleted. In many places nothing remains but shells; in others even the shells either have been taken away or are covered by silt. On the other hand, the abundant oyster larvæ present during the spawning season cause a very heavy set and overcrowd every suitable object above low-water mark. One of the remarkable peculiarities of the Georgia oyster beds is the fact that sets are never found below low-water mark. Insufficient cultch is responsible for crowded conditions on the beds and the formation of "bunch oysters", but there is nothing to prevent the production of the best type of oyster in Georgia waters by transplanting seed oysters to deep water. The survey shows that the extensive coastal waters of Georgia are suitable for oyster culture and can be exploited with profit.

The following specific recommendations for the development of the oyster industry in the State were based on this survey:

1. Existing laws with respect to returning shells to the natural oyster beds, including supervision thereof and control as to time and place of planting, should be strictly enforced.

2. Small-scale experimental oyster farming should be developed at once. It was suggested that brush or shell be scattered between tide marks on several particularly favorable sites in order to obtain set, and that later the seed oysters be transplanted below low-water mark. These beds should be kept under constant observation, and salinity and temperature records should be taken at least once weekly.

3. Seed or adult oysters should be planted on depleted beds in order to restore them, and these beds should then be closed to fishing by the public for at least two years.

4. New oyster beds should be established in suitable localities above low-water mark.

In the summer and fall of 1925 experiments were conducted by Dr. P. S. Galtsoff at Woods Hole, Mass., to determine the effect of temperature on the feeding of oysters. With apparatus built especially for this purpose, it was possible to measure accurately both the rate of flow and the volume of water passed through the gills. It was found that sucking water is a function of temperature. The water reaches its maximum flow at 77° F. and retards with the lowering of the temperature. Below 45° F. no current is produced, although the cillia of the gill epithelium continue to beat; at 41° F. all motion ceases.

These observations furnish direct evidence on the much discussed theory of hibernation advanced several years ago by the bacteriologists, Prof. F. P. Gorham and Dr. H. D. Pease, who made the interesting statement that during the cold season the bacillum coli scores or ratings of oysters taken from the polluted beds are always very low. The present experiments show that this is because no water is taken in by the oyster when the temperature is low.

By analyzing the water that had passed through the oysters' gills, Doctor Galtsoff discovered that over 99 per cent of the diatoms and dinoflagellates consumed by them are caught by gill the epithelium. The discharged water contains almost nothing but mucus. However, the experiments made by him in October in Doctor Pease's New York laboratory show that only a very few bacteria are retained by the gills, most of them passing through the gill cavity. Bacillum coli alone were used in the experiments. It is believed that these laboratory e periments will be effective in solving the various practical problems of oyster culture and sanitary control of the oyster industry.

In order to determine which are the best methods for maintaining and increasing the natural supply of oysters, additional experiments were conducted at the shellfish laboratory at Milford, Conn., relative to the life history, habits, environment, culture, and artificial propagation of the oyster. Milford Harbor is typical of the numerous coves, bays, and estuaries that are the natural habitat of the oyster, and in former times shellfish were very prolific there, so that scientific data derived from detailed study of the oysters present in this small body of water can be used as the basis for developing oyster culture in other localities.

To rehabilitate this small harbor, the Connecticut Oyster farms Co. supplied oysters enough to establish two fair-sized spawning beds, one of which was located on the tidal flats and the other in the channel. As these waters are at present unpolluted to any serious degree it is possible to study the oyster under conditions similar to those under which it thrived in years past.

A brief résumé of the various studies and experiments made and the results obtained follows.

Spat collection.—The tidal flats in the harbor were planted with brush, shells, and tile collectors, each of which successfully demonstrated the value of such flats for producing annual harvests of seed oysters. The birch brush, which was planted in rows and stacks over an area of about 6 acres, was covered with a good set of oysters for a distance of 2 feet above the bottom, and after the oysters had attained a good size, the brush was transplanted to the deep-water beds in the sound.

At the suggestion of Capt. Charles E. Wheeler, manager of the Connecticut Oyster Farms Co., a dozen wire baskets were filled with oyster, clam, and mussel shells and placed on the flats. These proved to be the cheapest and most practical type of collector used in the experiments. Each of the shells on the top, bottom, and sides of the baskets was covered with from 100 to 200 spat, those in the layer just inside were covered with from 12 to 50 each, and those in the very center caught from 2 to 10 spat each. Each bushel of oyster shells caught about 15,000 spat, while the baskets of clam and mussel shells caught a few thousand less than this. This method can be made even more efficient by using the large, brittle oyster shells from the Housatonic River, which make it possible for more spat to attach in the center of the baskets and which, after being transplanted to off-shore grounds, easily break up, allowing the young oyster ample room for growth.

Another type of collector used in the experiments was half-round, glazed tile, having a surface of about 1,000 square inches. The average number of spat collected by each tile from the first set of oysters

was 1,500, and from the second, which was heavier, 4,000. After the spat had attained their summer growth, they were easily detached from the tiles without injury and planted as single seed oysters; in a few years they will have developed into "select" stock, the most valuable product produced in this fishery.

The location and arrangement of the various collectors had an effect on the time and condition of tide when and depth and vertical range at which setting takes place, and valuable data on these points were collected. Shells and rocks scattered about the harbor also were covered with spat, and from a small bar near the brush plantings over 100 bushels of gravel, heavily set with oysters, were collected.

The countless millions of seed oysters produced as a result of the incomplete restoration of this harbor evidence the value of these inshore areas to the oyster industry and the necessity of protecting them from overfishing and pollution.

Life-history studies.—Spawning records were obtained from three lots of ripe oysters, of 10 bushels each, kept under close observation in a float. In each experiment, almost all of the oysters spawned vigorously and simultaneously. Spawning occurred at 24.1°, 22°, and 23° C., when the tide approached high-water mark. Records of salinity and hydrogen-ion concentration were made at the same time. The oysters on the spawning beds in shallow and deep water became ripe much sooner than usual this year and discharged their spawn on about the 6th and 13th of July.

Plankton collections were made in Milford Harbor and Long Island Sound for the purpose of determining the abundance, distribution, and growth of the free-swimming oyster larvæ prior to setting. The collections made from 1921 to 1924 gave evidence of a strange disappearance of the larvæ from the time they were one or two days old until they were nearly ready to set. Similarly, careful pumpings and tows made in 1925, from the surface of the water to within a few inches of the bottom, contained very few oyster larvæ of the intermediate sizes. From observations of the behavior of artificially propagated larvæ of these sizes it was apparent that they were not only clamlike in structure but in habit as well, and capable of plowing their way through sand and loose dirt by means of a long, muscular foot. Several sections of bottom, about one-half inch thick, were taken up near one of the spawning beds, placed in one of the hatching tanks, and supplied with a good stream of water. After several hours, an examination of the bolting-silk net placed at the overflow revealed many of the long-sought, intermediate-sized larvæ, though it was impossible to determine whether they had been on the bottom or merely lying between the sand grains when the samples were collected. The discovery of this interesting habit enables us to understand better the relationship between spawning beds and setting areas and the effect of tides, waves, and currents on the distribution of the larvæ.

By arranging floating and stationary spat collectors from the bottom of the channel to high-water mark, the following observations on "setting" were made: First, that attachment of the greater proportion of larvæ occurred with the beginning of flood tide and continued for about two hours. Second, that the vertical distribution of the spat took place from the bottom (30 feet below the surface) to within

about 2 feet above low-water mark. Third, that the horizontal distribution in the vicinity of Milford was from the deep-water beds 2 miles offshore to areas in the harbor that are covered after the first two hours' run of the flood tide. Fourth, that the greatest concentration of spat per square inch was found in a zone 10 to 12 inches above low-water mark. Records of the rate of growth of the spat under various conditions were made from July 18 to September 20.

Environmental conditions.—Six stations located in Milford Harbor and the adjacent inshore waters of Long Island Sound were regularly visited, and observations of general hydrographic conditions were made. Water temperatures were unusually high, ranging from 20° to 25° C. on the bottom from July 15 to August 20, and attained a maximum ebb-tide temperature of 29° C. in the harbor on August 19. The salinity ranged from 25 in June to 26 and 27 during July and the first part of August, a marked increase occurring the last two weeks in August, when there was very little rainfall. The hydrogen-ion concentration was determined by the prism-comparator method using cresol red and brom-thymol blue as indicators.

Commercial oyster culture.—The best and most general set of oysters since 1914 was obtained in 1925 throughout the oyster-growing region of Connecticut with the aid of unusually favorable weather and water conditions. At the present time a set of commercial value in these waters depends upon the early ripening and spawning of the oysters on the inshore and offshore beds of Long Island Sound, as these are the only ones large enough to produce a sufficient quantity of spawn. In the past when the oyster industry succeeded in obtaining a crop of oysters almost every year, large, natural beds were situated in the harbors, bays, and river mouths, where conditions were favorable for the production of large quantities of spawn. Today almost all of these valuable spawn-producing and shellfish-growing areas have been destroyed by excessive pollution and overfishing, so that only the deep-water beds are left for the production of seed oysters.

When conditions existing on these deep-water beds in spring and summer are such as would ordinarly exist in the harbors and estuaries, oyster culture is successful, but unfortunately this happens rarely. The climatic and hydrographic records for the summer of 1925 reveal that precipitation, river discharge, air and water temperatures, and salinity were unusual and produced the desired harborlike conditions in the sound, which resulted in successful deep-water oyster culture. The State of Connecticut recently passed an act creating a State water commission with power to enforce the adoption of reasonable and practical measures for controlling, reducing, and eliminating pollution. No greater improvement could be made for maintaining and increasing the oyster supply of Connecticut than the restoration of its harbors and rivers.

CLAMS OF THE PACIFIC COAST

During 1925 the clam investigations on the Pacific coast were continued by Dr. F. W. Weymouth, of Stanford University, and H. C. McMillin, scientific assistant. Field work was carried on from April to September, during which time two months were spent on the Washington beds getting more exact spawning data and records of

the environmental conditions. Three sections were studied especially to determine the difference in physical factors and how these are reflected in growth.

The onset of spawning was observed and studied at Cordova for the first time. The water was colder than on the Washington coast when spawning began, but the same relative change in temperature appears to incite the action. Discharge of eggs begins slowly and becomes more rapid after one day, but spawning never takes place as rapidly as it does in Washington. No information has been received about the set that resulted from the 1925 spawning, but usually there are fewer young in Alaska than on the Washington beds.

When the field work was performed in 1924 it was noticed that razor clams in various localities seemed to become sexually mature at a common size rather than at a common age. In working up these data, therefore, the influence of size and age on sexual maturity was especially observed, and in addition the relation between size and age was determined for various localities.

As razor clams in Washington grow approximately twice as fast as do those in Alaska, it is of economic importance to determine whether they really become spawners in one-half the time. It was found that the older clams average a smaller size at maturity than the younger ones. Specimens from Washington matured in less than half the time required by those from Cordova, but the Cordova specimens averaged more than one-half centimeter smaller in size. Figures from all the beds showed that 1 centimeter in size was approximately equal to 10 years in age in sexual maturity.

Proportional measurements of razor clams from beds in California, Oregon, Washington, British Columbia, and Alaska indicate that the economically important forms all belong to a single species rather than to several, as asserted by some systematists.

A report was published in 1925 covering the results of the investigations made in 1923 and 1924.

SCALLOPS

Because of a sudden great reduction in the number of scallops, the Fisheries Commission Board of North Carolina requested the bureau to make an investigation, and J. S. Gutsell was assigned to the work.

The scallop fishery occupies an important place among the fishery industries of the State and is an extremely important one among those of Carteret County, to which it is confined. In recent years it has approximated in financial importance the oyster industry of the entire State, with an annual value of nearly $250,000.

A survey made by the Fisheries Commission Board during the summer of 1924 was reported to have revealed an unusually great and widespread abundance of scallops. A later survey, following unprecedentedly heavy rains, showed almost complete mortality except over unaffected areas in lower Bogue Sound. The scallop fishery confirmed these findings, revealing scallops in great abundance wherever they are found at all. Although direct evidence is lacking, there seems to be no reason to doubt that unusually low salinities resulting from abnormal rains caused the mortality.

Dredging surveys made by Mr. Gutsell and a representative of the Fisheries Commission Board revealed scallops in appreciable numbers in one small area only, a truly alarming outlook. However, by wading over suitable flats near the Beaufort laboratory scallops were found in considerable numbers in a few places. These areas had been devastated by floods the preceding season and made apparently barren, so that no satisfactory explanation for their fertility in 1925 can be given.

Small or seed scallops were very scarce early in the summer, but were obtained in moderate numbers late in the summer and became somewhat more abundant, though probably not normally so, as time passed.

Measurements of adult scallops show a fairly even and rapid growth from mid July to mid September, a lack of further growth until mid November, and thereafter moderately rapid growth, with no indication of cessation at the end of the year. This renewed growth is also clearly revealed by examination of the shells. The late fall growth was altogether unexpected. The only phenomena with which it seems reasonable to connect the nongrowing period are sexual functionings of some sort. Possibly metabolic activity is diverted from shell growth to the production of spawn.

The bay scallop is one of the shortest lived of commercial bivalves. In the north, it has been shown that in the majority of cases individuals die during or after their second winter and before spawning time the following summer—that is, before the scallops are 2 years old. Although the prolonged spawning complicates matters and data are insufficient for any positive statement as to length of life, there seems to be little doubt that there is a distinct resemblance between the later life histories of scallops in northern and southern waters.

The scallop is a hermaphroditic species. It is presumed to commence spawning some time in the spring in North Carolina. Observations made in July showed that some scallops had spawned, and spawning was observed in August and continued to the end of December. In mid December about half of the scallops contained considerable quantities of spawn and about a quarter of them had large quantities. Evidently observation over a period of at least a year is necessary for even approximate knowledge as to when spawning begins and ends.

Recommendations for the protection of the scallop beds have been made to the State Fisheries Commission Board based on the results of this investigation. Some of these have already been favorably acted upon, and it is anticipated that further action will be taken in the near future.

FRESH-WATER MUSSELS

In addition to the regular annual survey of certain mussel beds of the Mississippi River by the shell expert of the Fairport (Iowa) laboratory, J. B. Southall, a special survey of the upper Mississippi between Lake Pepin and La Crosse was conducted by Dr. N. M. Grier, of Dartmouth College. A similar survey over the same territory was made by Doctor Grier in 1920.

The rearing of mussels in hatchery troughs was continued, but this work was subordinate to the researches of Dr. M. M. Ellis, of the University of Missouri, special investigator at the Fairport laboratory during the past summer. Doctor Ellis studied the elimination of the parasitic period in the culture of fresh-water mussels and made very material headway in this direction. He also definitely determined the importance of the acid-alkali balance of the blood of the fish to the glochidia encysted in its gills. This proved to be an important factor in the cultivation of mussels without host fishes. This work will be continued.

Doctor Ellis also worked on the effect of light upon the glochidia of mussels. He determined that the unfiltered, ultraviolet rays of direct sunlight are quickly fatal to glochidia, and that if only partially filtered they may cause disturbances seriously affecting the development of the glochidia. Juvenile mussels also appear to be sensitive to ultraviolet rays, which confirms the observation made by Dr. A. D. Howard that a greater proportion of juvenile mussels survives when they are shielded from light.

TERRAPINS

The experiments in diamond-back terrapin culture, which have been conducted at the Beaufort (N. C.) biological station for a number of years, were continued with success. More information is being gained all the time relative to the requirements of the terrapins. One of the most important recent contributions, from an economic standpoint, had to do with crowding, it having been shown that many more terrapins than it was formerly thought advisable to hold can be held in an inclosure when a supply of clean water is available. Stagnant or dirty water is extremely detrimental, especially when the animals are crowded. This work is under the supervision of Dr. Samuel F. Hildebrand, and is in the immediate charge of Charles Hatsel.

The total number of terrapins removed from the egg beds during the fall of 1925 was 2,968. The total number taken from the egg beds in the fall of 1924 was 3,458. The main cause of the decrease in the number of terrapins hatched in 1925 was the decline in the number of eggs laid by the original breeders, some of which have been at the station since 1902 and others since 1906. All of these were mature when confined, and some of them, no doubt, were already very old. It remains to be seen whether the decrease is due merely to the normal yearly fluctuations that have taken place previously or whether a permanent decline (possibly due to old age) in eggs and young produced has set in.

A cooperative arrangement has been entered into with the Fisheries Commission Board of North Carolina for hatching and liberating young terrapins with the view of restocking the sadly depleted State waters. The Fisheries Commission Board has impounded 488 adult terrapins at the biological station for breeding purposes, and is supplying their food and a man to assist in feeding and otherwise taking care of the terrapins. Arrangements have been made to build another pound and to extend this work.

ECOLOGICAL AND OCEANOGRAPHIC STUDIES

CONTROL OF MOSQUITOES BY MEANS OF FISH

Investigations relative to the use of fish for controlling mosquito breeding were continued at Greenwood, Miss., in cooperation with the United States Public Health Service. This work was under the supervision of Dr. Samuel F. Hildebrand and in immediate charge of Irving L. Towers. The season was favorable until the latter part of September, when heavy and continuous rains set in and the work was abandoned for the season.

Gambusia continues to give better results than any other fish. In fact it no longer seems worth while to give consideration to any other species in connection with mosquito control in regions where Gambusia is common. In general, Gambusia provides mosquito control just to the extent that it is able to reach the larvæ. Complete control is rarely possible, but the presence of this fish always brings about a very large reduction in mosquito production.

OCEANOGRAPHY

At the request of the New York Zoological Society, two members of the bureau's scientific staff, Dr. Charles J. Fish and Marie Poland Fish, were detailed to join the *Arcturus* oceanographic expedition, the former to supervise the oceanographic work and the latter to investigate the distribution and early development of ocean fishes. The cruise lasted six months, February 14 to July 30, 1925, during which time the Gulf Stream, Sargasso Sea, North Equatorial Current, Antilles Current, Mexican Current, and the Galapagos and Cocos Island regions were investigated. In all 113 stations were made and numerous collections of plankton and many physical and chemical data were secured. Any conclusions drawn at this time must necessarily be of a very general nature and subject to modification or change when the data have been studied more carefully.

The *Arcturus* entered the Pacific during a recurrance of the dreaded El Niño, a warm, counter water mass from the north, which about once in 20 years penetrates along the South American coast as far as Peru, carrying tropical fishes and other marine forms far beyond their usual range in this area and causing enormous destruction to the life of the cold Humboldt Current as well as to the guano birds, which rely upon pelagic marine organisms for food. The loss to Peru in guano alone at such times is tremendous and forms a problem of national importance. Temperature sections taken by the *Arcturus* in this region indicate that El Niño does not in reality divert the Humboldt Current from its course, as is popularly believed, but flows over it as a comparatively thin film. Everywhere in the Galapagos region Humboldt temperatures were encountered below 100 meters. It is therefore highly improbable that a warm and consequently lighter current of temporary nature pushed aside the permanent cold and heavier Humboldt Current by wedging between it and the coast, particularly as previous records show the latter body of water to be of a slightly higher salinity.

The vertical distribution of life in the ocean formed one of Doctor Fish's most important problems. Everywhere the same zones could

be distinguished but were found to vary somewhat in the position of their upper and lower boundaries as well as in the richness of the distinct animal communities characterizing them. Temperature, light, and pressure appear to be the most important physical limiting factors. As all life in the lower levels ultimately depends for food upon organisms that descend from the surface waters, collections from even the deeper zones in such areas as the Gulf Stream and about the Galapagos Islands, where an abundance of surface life exists, were exceedingly rich. Conversely, in barren areas like the Sargasso Sea, where the surface fauna is scanty, the intermediate levels are very sparsely inhabited; in fact, so scarce was the animal life that it was at times impossible to determine faunal limits. Although poor in species, the zone yielding the largest hauls was situated just below the depth to which surface animals descend in the daytime. This hitherto unrecognized zone, between 400 and 700 meters, is now named the "transition zone," as it comprises the zone of transition from daylight to darkness. It adjoins the lower part of the "silver zone," recently used in classifying the vertical distribution of fishes lying within the limits of 150 to 500 meters. Below 2,000 meters and above the bottom community, there appears to be a region (recorded first by the United States fisheries steamer *Albatross*) visited only by scattering forms or falling dead bodies. Although this theory has at times been attacked, the *Arcturus* collections substantiate in every respect the observations of Mr. Agassiz for those particular regions traversed.

Enormous schools of tuna observed between Mariato Point and Cocos Island from May 11 to June 3 were apparently making their annual migration. A brief report on them has been submitted to the bureau.

Progress has been made in working up the data collected during the hydrographic and biological survey of Chesapeake Bay, and it is anticipated that the final report will be completed within a comparatively short time.

The study of the currents, temperatures, etc., in Massachusetts Bay has already been mentioned in the discussion of the investigations of the early life of the cod, pollock, and haddock. A report on certain phases of this investigation was prepared and submitted by Richard Parmenter, temporary assistant.

The comprehensive investigation of the oceanography of the Gulf of Maine, which has been conducted for a number of years by Dr. H. B. Bigelow, of the Museum of Comparative Zoology, Harvard University, is nearly completed. The section dealing with the fishes has been published already, that dealing with the plankton is in the hands of the printer, and the section dealing with the physical oceanography is in an advanced stage of preparation.

In cooperation with the Bureau of Lighthouses, water temperatures have been taken at a number of selected stations along the Atlantic coast.

ECOLOGY OF FRESH-WATER LAKES

During the summer of 1925 limnological observations were made on some 50 lakes in northern Wisconsin by Dr. Chancey Juday of the State Geological and Natural History Survey. Most of these lakes are situated in Vilas County and range in area from 3 to 1,500

acres and in maximum depth from 2 to 35 meters. During the summer of 1925 the surface temperature was as low as 19° C. in some of these lakes and as high as 24° C. in others.

These bodies of water may be regarded as having soft water, as they have only a relatively small amount of calcium and magnesium in solution. Several, which have neither an inlet nor an outlet, contain less than 2 cubic centimeters of fixed carbon dioxide per liter; most of them have between 5 and 12 cubic centimeters per liter.

The epilimnion, or upper stratum of water, in these lakes was well supplied with dissolved oxygen, the amount ranging from 5 to 7 cubic centimeters per liter of water. In some of the deeper ones the the hypolimnion, or low water, possessed very little or no dissolved oxygen at all in late July and in August.

In the lakes having a depth of 5 meters or more the lower water generally yielded a larger amount of free ammonia than the upper stratum; the reverse was true of some of the lakes that possessed a relatively small amount of plankton. The quantity of free ammonia found in the upper water of the various lakes varied from a minimum of 0.024 to a maximum of 0.148 part per million; this represents a sixfold difference. In the lower water the quantity of free ammonia ranged from a minimum of 0.020 to a maximum of 0.968 part per million.

The theory has recently been advanced that the quantity of phytoplankton produced by a body of water is dependent upon the amount of phosphorus that is available in the water. In order to see whether such a correlation could be established for these lakes, a quantitative study of the phosphorus was made, but the data obtained in 1925 do not warrant any definite conclusions. It was found that the quantity of phosphorus in the upper water ranged from none at all to a maximum of 0.095 milligram per liter of water. No phosphorus was obtained in the lower water of one small lake that is only 7 meters deep, but the lower water of all of the other lakes yielded a measurable amount of phosphorus. The quantity varied between 0.005 and 0.09 milligram per liter in most of the lakes. A maximum of 5 milligrams per liter was noted in a lakelet only 122 meters (400 feet) in diameter, but which is 22 meters (72 feet) deep.

The lowest readings for hydrogen-ion concentration were obtained in 11 lakes that have less than 2 cubic centimeters of fixed carbon dioxide per liter of water; in this group the reaction ranged from pH 6.9 at the surface to pH 5.4 at the bottom. It will be noted that all of these readings were on the acid side. In the lakes that had more than 2 cubic centimeters of fixed carbon dioxide per liter of water the surface water was neutral or alkaline (pH 7.1 to 9.4), while the bottom water of some of them was acid and of others neutral or alkaline (p H 6.4 to 7.6).

The total plankton varied from a minimum of 545 to a maximum of 6,990 milligrams of dry organic matter per cubic meter of water. In general, the shallower lakes yielded a larger amount of plankton per cubic meter of water than the deeper ones. The maximum was obtained from the surface water of a lake having a maximum depth of only 8 meters.

A few quantitative observations were made on the larger bottom-dwelling animals, but only a very limited amount of time could be spent on to this phase of the general investigation. An interesting

observation may be noted in this connection—it was found that *Mysis relicta* leaves the bottom of Trout Lake at night and migrates to the surface.

FOULING OF SHIPS' BOTTOMS

The investigation of the fouling of ships' bottoms was continued during 1925 both at New York and at Beaufort, N. C. This work involved the examination of about 50 ships in dry dock and considerable experimental work at the Beaufort laboratory, and finally a complete report covering all of the work has been submitted.

On the basis of careful examination of 250 ships at the time of dry-docking, it has been ascertained that fouling is caused by both plant and animal growths, the latter being the more important wherever fouling was at all extensive. These were barnacles, hydroids, algæ, tunicates, bryozoa, mollusks, and protozoa, in the order of frequency and usual abundance.

It was soon noted that fouling organisms were almost exclusively those forms commonly found on rocks near shore, especially in harbors, and it was found, furthermore, that fouling occurs almost entirely while vessels are in port. Most ships were found to be moderately fouled after 6 or 8 months from the date of previous dry-docking, and it was shown that the time that elapses between dry-dockings is of significance, for fouling increases with the interval of time. However, fouling was least on ships that spent most of their time cruising at sea.

The data regarding relation of light to the amount and kind of fouling, a relationship early noted on ships' bottoms, have been supplemented by extensive experiments that demonstrate that light in the field of green and blue-green has the maximum stimulating efficiency for the cyprid larvæ of several barnacles, and that at the time of attachment these forms are negative to light.

The relation of fouling to fresh water was also studied experimentally, and it was demonstrated that fresh water kills, within 72 hours, most of the organisms that cause fouling; but if calcareous growths have already formed, such materials remain, and the resistance to the movement of the ship is not materially reduced.

A preliminary study of seasonal periodicity indicates that the amount of fouling on a given ship can be predicted from a knowledge of seasonal periodicity for the organisms in the ports visited. Indications of a selective process of attachment by barnacles have been noted, indicating a relation between attachment and the nature of the surface.

INVESTIGATIONS PERTAINING TO FISH-CULTURAL OPERATIONS

PHYSIOLOGY AND NUTRITION OF FISHES

Feeding experiments with fingerling trout were carried on during the summer of 1925 at the Holden (Vt.) hatchery by M. C. James, under the supervision of Dr. H. S. Davis. As previous experiments at Manchester, Iowa, and White Sulphur Springs, W. Va., with rainbow-trout fingerlings gave such encouraging results, it was decided to conduct similar experiments at a brook-trout station. For this purpose, brook-trout fingerlings were divided into lots of 1,000 each

and were fed on a diet of sheep liver and beef heart to which 1.5 per cent of cod-liver oil and 2 per cent of dried brewer's yeast had been added. The results of this experiment showed that with brook trout no practical benefit is derived from the addition of cod-liver oil and yeast, either individually or in combination. In some cases apparently an increased growth followed the addition of these accessories, but as mortality also increased in such cases it is probable a selective action may have been in effect. It is logical to assume that the survivors were the larger, more vigorous fish, which would account for the higher average individual weight.

These results are in striking contrast with those obtained during the previous two seasons with rainbow fingerlings, where the beneficial results from the addition of oil and yeast were clear and unmistakable. The explanation of such diverse results with the two species of trout is not obvious, and furthur investigations are necessary before the matter can be cleared up. However, there is some evidence that in the case of the rainbow trout the beneficial effects of the cod-liver oil may be associated with an obscure disease that is prevalent among the rainbow fingerlings at the hatcheries where these experiments were conducted. This disease is characterized by the accumulation of crystals and casts in the kidney tubules. The water at these hatcheries is rich in calcium and magnesium bicarbonates, and it is not impossible that the disease is the result of impaired calcium metabolism, in which event the reason for the beneficial effect of cod-liver oil is apparent. For some unknown reason brook trout do not appear to be as susceptible to this disease as the rainbows. The lack of similar results from the addition of yeast to the diet of the brook trout may be due to the fact that in many cases the yeast was found to develop, for a short time at least, in the intestines of the fish. No such growth has been observed in the rainbows.

The reason for the failure of the experiment was not as clear in the case of oil as with the yeast, and further experiments with oil are planned for the coming season. The results of some experiments conducted for the bureau at the Connecticut State hatchery at Burlington, Conn., in which 1.5 per cent of cod-liver oil was added to beef liver fed to brook-trout fingerlings, indicate that the addition of the oil was beneficial.

As in previous experiments, beef heart was found to be a more desirable diet for young fingerlings than sheep liver, both as regards mortality and rate of growth. As the fish grow older, the advantages of the heart diet become less, and after two or three months the liver-fed fish may reach a larger size than those kept on a heart diet.

For the purpose of testing the effects of stale food on fingerling trout, 2,000 brook-trout fingerlings were divided into two lots of 1,000 each. One lot was fed "fresh" liver, the other "stale" liver that had been kept in tne ice box for a week or more. This liver was noticeably stale or sour but had not begun to putrefy. From the very beginning of the experiment, which was continued from July 9 to August 11, the fish fed "stale" liver showed a much higher mortality and slower growth than the controls, which were fed fresh liver. The total mortality in the former lot was 41.2 per cent, and the average individual weight increased from 0.412 grams to 0.722 grams.

In striking contrast with this, there was a total mortality of 16.7 per cent and an increase in the average individual weight from 0.445 to 1.135 grams in the control lot.

The feeding experiment at the Wytheville (Va.) station, mentioned in the previous report, was discontinued on April 29, 1925. In this experiment rainbow-trout fingerlings were divided into two lots of 2,000 each. One lot (the controls) was fed a straight heart diet, while small quantities of cod-liver oil and dried brewer's yeast were added to the beef heart fed to the other lot. Throughout the experiment there was a marked contrast in the mortality of the two lots. The total mortality from May 29, 1924, to April 29, 1925, in the lot fed a diet containing oil and yeast was 44.1 per cent; while in the control lot, which received only beef heart, the loss was 82.8 per cent. The high mortality in both lots was, no doubt, due in part to the fact that the fish were kept in ordinary hatchery troughs throughout the course of the experiment and, in the case of the vitamin-fed lot, became badly crowded before the experiment was terminated. Yet, in spite of this fact, the mortality in this lot was much lower than among the controls up to the very end of the experiment. This experiment is especially significant because it was conducted under ordinary hatchery conditions and continued for a much longer time than any other of the feeding experiments.

HOLDEN EXPERIMENT STATION

During the past year arrangements were made to utilize the Holden, Vt., substation for experimental work in cooperation with the division of fish culture. Such an experimental station is badly needed, as it will provide an opportunity to investigate various problems connected with the artificial propagation of trout and other fishes, for which purpose the Holden station is well adapted. The hatchery is supplied with both brook and spring water, which can be mixed in any proportion required. There is also ample room for the construction of ponds of various types, which will be of great value in experimental work.

Experiments were begun at the station during the spring of 1925, but owing to lack of equipment it was possible to hold only a small number of trout through the summer. For this and other reasons the work during the summer was of a purely preliminary character. Several ponds were constructed and others will be added as soon as funds are available. A small laboratory has been fitted up at the station, and with the increased facilities available it will be possible during the coming season to carry on extensive investigations in the nutrition and diseases of trout. It is also planned to conduct systematic experiments in selective breeding in the hope that it will be possible to produce a more vigorous and hardier race of brook trout better adapted to hatchery requirements.

In addition to the work at the station, a series of field investigations is contemplated primarily for the purpose of obtaining more definite information regarding the results of artificial propagation and the possibility of increasing its efficiency. There are numerous native trout streams in the vicinity of the station, which will afford an excellent opportunity for investigations of this nature.

PATHOLOGY

As noted in the last report, the bureau, at the request of the Eastern Trout Growers Association, undertook an investigation of the so-called "soft-egg" disease, which during the last few years has caused serious losses among brook-trout eggs at a number of commercial hatcheries in New England. Owing to the short time during which the disease is prevalent, it was impossible to complete the investigation during the season of 1924. However, it was found that the trouble is due to an external parasite, possibly an ameba, which forms small holes in the egg membrane. A continuation of the investigation was planned for the spawning season of 1925, and for that purpose M. C. James visited some of the hatcheries, but no trace of the disease could be found. With one exception, all the hatcheries reported an entire absence of the disease throughout the season. In the case of the single exception noted, a slight outbreak occurred in one trough late in the season but was quickly brought under control.

The absence of the disease during the spawning season of 1925 from hatcheries in which formerly it was prevalent can only be ascribed to the use of thoroughly sanitary measures, which were adopted on the bureau's recommendation when the disease was found to be due to an external parasite rather than to some obscure cause such as improper food.

At the request of the Connecticut State Board of Fisheries and Game, Dr. H. S. Davis made an investigation of an outbreak of a little-known fin disease at the State hatchery at Burlington, Conn. This disease apparently has been prevalent for several years at the Windsor Locks hatchery, where it has caused serious mortality, and evidently was introduced into the Burlington hatchery with fish transferred from Windsor Locks. The disease causes the fins to become badly frayed, the dorsal and caudal fins being affected most seriously.

Owing to the pressure of other work, it was impossible to devote sufficient time to the disease to arrive at any definite conclusion as to its cause. However, the experience of the hatchery staff indicates that the disease can be controlled by the use of a dilute solution of potassium permanganate followed by strong salt baths at frequent intervals.

POLLUTION

At the request of the Louisiana State Conservation Commission, Dr. H. S. Davis made an investigation of pollution in the Dorcheat Bayou from the surrounding oil fields, of which there are several. Numerous complaints had been received by the commission that pollution from the oil wells had resulted in serious mortality of fish in the bayou. It was found that under ordinary conditions pollution from the oil fields was sufficiently dilute so as not to affect the fish in the bayou seriously, although practically all life was destroyed in small tributary streams that drained the oil fields. However, during periods of exceptionally low water, which occasionally occur, many fish are killed below the point where the pollution enters the bayou.

EXPERIMENTAL WORK IN FISH CULTURE

Further attempts were made to cultivate of the shovel-nose sturgeon (*Scaphirhynchus platyrhynchus*) and paddlefish (*Polyodon spathula*) at the Fairport (Iowa) laboratory, without results. The culture of channel catfish, buffalofish (*Ictiobus bubalus*), bluegill sunfish, crappie, and largemouth bass was conducted at this station on a large scale. Effort was made to fully develop the fish-cultural possibilities of the station in the belief that this would be of benefit in promoting the further development of present pond-cultural methods. The surplus fish were distributed to applicants.

One small pond was again devoted to the rearing of sheepshead (*Aplodinotus grunniens*), this time with success. While at present this fish is popular only in small sections of the country, the fact that it has good food qualities and thrives well in certain waters was believed to warrant a study of its pond-cultural possibilities.

INSPECTION OF THE SPONGE FISHERIES

The inspection of the sponge fishery centering at Tarpon Springs, Fla., was conducted as usual by Walter Topliff, inspector of sponge fisheries. A total of 547 vessels was inspected, 212 at sea, 256 at Tarpon Springs, and 79 at Cedar Key. In addition, the inspector made regular examinations of the catch while it was being sorted, arranged on strings, and sold at the sponge exchange at Tarpon Springs.

The value of the sponges taken from the Gulf of Mexico along the coast of Florida remains almost constant, although the number of bunches fluctuates from year to year, largely due to the unstable demand for the cheaper grades. However, there apparently is a slight downward trend in the production and a noticeable decrease in the number of sponges of the larger sizes. These are undoubtedly evidences of the depletion of the fishing grounds, which have been intensively exploited for many years. It is stated that no new grounds have been exploited in the past 10 years although a few trips have been made to the westward of Cape San Blas, but with such poor results that they were not repeated. Sponge beds of considerable extent exist in the deeper waters in the vicinity of Key West, which are lying dormant due to the inability of the Key West spongers, who use only hooks and poles, and the Greek divers of the northern field to agree on working conditions. If the Key West field could be made available to the divers, it would help to relieve the too great intensity of fishing that exists at present in the Tarpon Springs field.

BIOLOGICAL LABORATORIES

During the summer of 1925 the laboratory at Woods Hole, Mass., was used more extensively than for many years. Its capacity, as well as that of the residence building, was taxed to the utmost to accommodate over 40 independent investigators and assistants. The increasing demand for these accommodations makes it imperative that the bureau change its policy with regard to the privileges of this laboratory. In the past very little selection was exercised because quarters were available for all applicants, but under present conditions

it is believed that the best interests of the bureau will be served if accommodations are accorded only to those who are working on problems of special interest to the bureau (especially problems in marine biology) and who have shown a capacity for energetic and productive research.

Some of the more important researches conducted at the Woods Hole laboratory during the summer of 1925 were as follows: Studies on the comparative composition of fish blood and the changes that take place during asphyxiation were continued by Dr. F. G. Hall, Dr. Lepkovsky, and Irving E. Gray. Dr. N. A. Cobb, of the Department of Agriculture, with several assistants, continued a study of the nematode fauna of the Woods Hole region. Dr. Edwin Linton and Dr. G. A. MacCallum carried on their studies of fish parasites, as they have done for many years past. Paul S. Conger, of the Carnegie Institution of Washington, working under the direction of Dr. Albert Mann, continued the study of the diatom flora, with particular attention to the bottom forms. Dr. C. B. Wilson carried on important studies in both parasitic and free-living copepods and among other things completed the examination of a large number of collections made by the *Albatross* and other research vessels of the bureau. Although these collections were old, they were well preserved and proved to be extraordinarily rich in new species. O. E. Sette, assistant in charge of the division of fishery industries, made use of the facilities of the laboratory in beginning an important investigation of the mackerel fishery. Dr. C. J. Fish and Marie Poland Fish returned from the *Arcturus* expedition in July and, with headquarters at Woods Hole, continued their studies of the plankton and larval fishes of Massachusetts Bay, which have been mentioned above. Dr. P. S. Galtsoff carried on important investigations on the feeding of oysters, as described in the section devoted to the oyster researches.

Work at the Beaufort (N. C.) biological laboratory has materially increased. Dr. Samuel F. Hildebrand, who was appointed director early in the year, took active charge of the station toward the end of June. James S. Gutsell was assigned to this laboratory in July and has undertaken an investigation (mentioned elsewhere in this report) of the scallop industry in Carteret County, N. C. Elmer Higgins, director of the Key West biological station, spent almost the entire year at the Beaufort station studying the life history of the striped mullet and other important food fishes. Dr. J. Paul Visscher and Robert Luce, who were engaged in a study of the prevention of the fouling of ships' bottoms for the Navy Department, made use of the laboratory during the summer. Seven independent investigators also availed themselves of the privileges of the station.

Prof. H. V. Wilson, of the University of North Carolina, made a survey of the local distribution of sponges and some other forms, as affected by recent changes in the harbor. It is found that a number of species are now missing where previously they were common or even abundant. Doctor Wilson believed that the increased activities in the harbor, particularly the dredging, and certainly, also, the heavy rains during the autumn of 1924, are responsible for the changes.

Dr. R. E. Coker, of the University of North Carolina, collected free-living copepods and identified the more common species. The material collected was retained by Doctor Coker for further study.

Dr. Bartgis McGlone, of the University of Pennsylvania, studied the effect of varying the hydrogen-ion concentration of sea water upon fertilization and rate of segmentation of the eggs of echinoderms. The results of this work could not be reported when Doctor McGlone left the station, because the necessary microscopical work in determining the results had not been completed.

Dr. W. C. George, of the University of North Carolina, spent a short time at the station making a histological study of the blood cells of certain species of ascidians.

W. R. Earle, graduate student of the University of North Carolina, studied and collected material bearing upon the regenerative processes in several forms of hydroids, and he also collected and preserved some material on the early embryological stages of Fundulus and the toadfish.

J. T. Penny, instructor in histology, Medical School, University of Tennessee, spent a very brief period at the station collecting and fixing specimens of Blanoglossus for study.

Miss Lorna W. Thigpen, graduate student of the University of Maine, spent several weeks at the station in a general study of invertebrate forms, principally with the view of familiarizing herself with the local fauna.

The Fairport (Iowa) biological laboratory has been mentioned in these pages in connection with the work with fresh-water mussels and in fish culture. T. K. Chamberlain is director. The fish-cultural investigations have been under the immediate direction of H. O. Hesen, superintendent, and H. C. Minch, foreman. As has been stated, Dr. M. M. Ellis, of the University of Missouri, and Dr. N. M. Grier, of Dartmouth College, were employed during the past summer in the mussel investigations. The regular staff was especially active in cooperating with various State and private organizations concerned with the conservation of aquatic resources.

Conditions at the Key West (Fla.) laboratory did not change during the year. The lack of adequate laboratory facilities made it impossible to conduct researches at this station, and the activities of the small resident staff were mainly directed toward the maintenance of the grounds and buildings.

During the year a new fisheries laboratory was established at Seattle, Wash., in temporary quarters kindly provided by the College of Fisheries of the University of Washington. The laboratory was opened under the direction of Dr. W. H. Rich and will be used as a center for the investigation of the fish and fisheries of the Pacific coast. During November and December certain of the salmon investigations were carried on here by Doctor Rich and H. B. Holmes, and it is planned to transfer the investigations on herring and clams to this laboratory in the near future. Such a laboratory has been needed for some time, and its establishment will do much to further the scientific work of the bureau on the Pacific coast.

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